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JANENE PEISKER
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AUSTRALIA

Patents Act 1990

PROVISIONAL SPECIFICATION

Name of Applicant	Indigo Technologies Group Pty Ltd
Address for Service:	CULLEN & CO Patent & Trade Mark Attorneys, 239 George Street Brisbane Qld 4000 Australia
Invention Title:	Particle agglomeration using vortex mixing

This invention is described in the following statement:

This invention relates generally to air pollution control and, in particular, to the removal of pollutant fine particles from air streams.

More specifically, the invention is directed to method and apparatus for promoting fine particle agglomeration and interactions using vortex mixing at particle scale, to thereby facilitate subsequent filtration or other removal of the particles from the air streams.

BACKGROUND ART

Many industrial processes result in the emission of small hazardous particles into the atmosphere. These particles often include very fine sub-micron particles of toxic compounds. As these fine particles are able to enter the human respiratory system, they pose a significant danger to public health. The identified combination of toxicity and ease of respiration has prompted governments around the world to enact legislation for more stringent control of emission of particles less than ten microns in diameter (PM10), and particularly particles less than 2.5 microns (PM2.5).

Smaller particles in atmospheric emissions are also predominantly responsible for the adverse visual effects of air pollution. For example, in coal burning installations, stack opacity is largely determined by the fine particulate fraction of the fly ash because the light extinction coefficient peaks near the wavelength of light which is between 0.1 and 1 microns.

The importance of fine particulate control can be appreciated by consideration of the number of pollutant particles in an emission rather than the pollutant mass. In fly ash from a typical coal combustion process, pollutant particles less than 2 microns in size may amount to only 7% of the total pollutant mass, yet account for 97% of the total number of particles. A process which removes all the particles greater than 2 microns may seem efficient on the basis that it removes 93% of the pollutant mass, yet 97% of the particles remain, including the more respirable toxic particles.

Various methods have been used to remove dust and other pollutant particles from air streams. Although these methods are generally suitable for removing larger particles from air streams, they are usually much less effective in filtering out smaller particles, particularly PM2.5 particles.

Many pollution control strategies rely on contact between individual elements of specific species to promote a reaction or interaction beneficial to the subsequent removal of the pollutant concerned. For example, sorbents such as activated carbon can be injected into the polluted air stream to remove mercury (adsorption), or calcium can be injected to remove sulfur dioxide (chemisorption). Additionally, particles can be made to agglomerate into larger particles by collision/adhesion, thereby improving the collectability of the particles, or the physical characteristics of the individual particles are otherwise changed to those of an agglomerate which is easier to collect and/of filter.

However, in order for these interactions to take place, the species of interest must be brought into contact. For many industrial pollutants in standard flue ducts, this is difficult for several reasons. For example, the time frames for reaction/interaction are short (of the order of 0.5 – 1 second), the species of interest are spread sparsely (relative to the bulk fluid) through the exhaust gases, and the scale of the flue ducting is large compared to the scale of the pollutant particles.

Normally, exhaust gases from the outlet of an industrial process are fed into a large duct which transports them to some downstream collection device (e.g. an electrostatic precipitator, bag filter, or cyclone collector) as uniformly and with as little turbulence/energy loss as possible. Such turbulence as is generated *en route* is normally a large scale diversion of gases around turning vanes, around internal duct supports/stiffeners, through diffusion screens and the like. This turbulence is always of the scale of the duct and is as brief as possible to achieve the desired flow correction.

Similarly, when mixing devices are employed for a specific application, eg. sorption of a particular pollutant, they are usually devices that generate a large-scale turbulence field (of the order of the duct width or height) and are arranged as a brief curtain/s that the gases must pass through.

It is also known to use vortex generators in mixing chambers to promote mixing of fluids. Again, the known vortex mixers create large-scale turbulence of the order to the dimensions of the duct or chamber.

Whether they be particulate (e.g. flyash), gaseous (e.g. SO_2), mist (e.g.

NO_x), or elemental (eg. Mercury), the pollution species which are the more difficult to collect within industrial exhaust flues are those of the order of micrometers in diameter (i.e. 10^{-6} metres). Due to their small size, they occupy a very small volumetric proportion of the total fluid flow. For example, one million 1μm diameter particles would occupy less than 0.00005% of the volume of 1 cm^3 of gas (assuming that the particles are spherical). Even at 10μm diameter, this proportion only increases to 0.05%. When it is considered that a pollutant such as Mercury may only account for a few parts per million (ppm) of the total species present, it is apparent that at particle scale, there is a significant amount of space/distance between the species being transported by an industrial flue gas. Large scale mixing, even by vortex generators, is therefore a "hit or miss" affair, and largely inefficient.

Furthermore, it is a characteristic of small particles entrained in a flowing fluid that they will follow streamlines in the fluid flow if there is insufficient force to move them out of that flow. That is, if the viscous forces of the fluid dominate the inertial forces of the particle, then the particle will follow the fluid. Known turbulent mixing regimes of the scale of the duct are many orders of magnitude larger than the particle. When viewed from the perspective of the particle, they are far from being chaotic but rather, are relatively smooth. Whilst there may be many changes of direction for a particle in its passage through a turbulent flow in a duct or through a standard mixing region, they are all relatively long range compared to the size or scale of the particle. Consequently, subsequent particles in a stream follow more or less the same path without interaction with the particles surrounding them. At particle scale therefore, there is relatively little mixing and consequently, the known mixing processes achieve poor efficiency in agglomeration.

Systems intended to maximise the collision rate of very small pollution species which occupy a tiny proportion of the volume of the total fluid flow must therefore concentrate them in mixing regions in which they are made to move along many trajectories at various velocities for as long as possible. Additionally these relative trajectories and velocities must be brought to bear at the scale of the particle to have the most effect. Unfortunately, current design philosophies do not adequately address these criteria.

It is an aim of the present invention to provide method and apparatus for achieving improved mixing or interaction of fine particles in airflows, either with the same species or other introduced species of larger particles, and thereby promote more efficient agglomeration of the particles or sorption by the larger particles.

SUMMARY OF THE INVENTION

In one broad form, the present invention provides a method of promoting mixing of fine particles in a fluid stream, comprising the step of generating turbulence in the fluid stream, characterised in that the turbulence is of such size and/or intensity that said fine particles are entrained in the turbulence and are subjected to turbulent flow at particle scale.

In another form, the invention provides apparatus for promoting mixing of fine particles in a fluid stream, characterised in that the apparatus comprises means for generating a turbulence in the fluid stream, the turbulence being of such size and/or intensity that said fine particles are entrained in the turbulence and are subjected to turbulent flow at particle scale.

Typically, the fluid stream is a gas or air stream, and the fine particles are pollutant particles of micron or sub-micron size.

Preferably, the turbulence is in the form of a plurality of vortices. In one embodiment, a multiplicity of small, low intensity vortices are used to entrain the fine particles and subject them to turbulent flow, thereby resulting in more efficient agglomeration of the particles. The larger, agglomerated, particles are subsequently easier to remove from the gas stream using known methods.

In another embodiment, one or more species of larger particles are introduced into the gas stream for removal of the pollutant particles. The fine pollutant particles are entrained in the vortices, but the larger particles are not, resulting in improved mixing and higher likelihood of contact between the pollutant particles and the larger species. When the pollutant particles contact the larger species, they tend to adhere thereto or react therewith, and can therefore be removed from the gas stream with the larger species.

The pollutant particles may be of gaseous, liquid or solid form. The larger species may be of liquid or solid form, e.g. liquid droplets.

Preferably, the gas stream is divided into a plurality of sub-streams, and multiple vortices are created within the individual sub-streams. For example, if the gas stream flows through in a duct, the duct may include formations to divide the gas stream into a plurality of parallel sub-streams across the duct. Multiple vortices are generated within each sub-stream longitudinally, i.e. along the gas stream.

Preferably, the Stokes number of the turbulent flow generated by the vortices is selected so that fine pollutant particles will be entrained, but not the larger removal species. Typically, a Stokes number much less than 1 will ensure entrainment of the fine pollutant particles. The larger removal species of particles should have a Stokes number much greater than 1 so that they are not entrained. In practical terms, the eddies or vortices generated in the gas stream are less than 10mm.

The removal species may be a chemical, such as calcium, which reacts chemically with pollutant particles, (such as sulphur dioxide) to form a third compound (e.g. gypsum). Alternatively, the removal species of particles may remove the pollutant particles by absorption, or by adsorption (carbon particles adsorbing pollutant mercury particles), or the removal species of particles may simply remove the fine pollutants by agglomerating with the pollutants through impact adhesion.

The invention therefore involves the creation of a multiplicity of small vortices which entrain the (small) particles of interest and subject them to turbulent flow. Larger particles are not necessarily entrained by these small vortices, or entrained to a lesser extent. Relative movement between the small and large particles results in higher frequency of collisions between them, and more efficient removal of the fine (pollutant) particles by the larger (removal) particles.

The use of a multiplicity of small vortices is counterintuitive. Normally, it is desirable that the pressure drop in the gas stream be as low as possible. For this reason, known vortex mixing systems normally use few vortex generators creating a large scale turbulence. The present invention, on the other hand, uses many vortex generators which create small scale vortices which entrain the fine (pollutant) particles in turbulent flow.

In order that the invention may be more fully understood and put into practice, an embodiment thereof will now be described by way of example only.

DESCRIPTION OF PREFERRED EMBODIMENT

A flowing fluid has a number of properties that define its state at any given point. The fluid properties of particular interest in this case are kinetic energy (proportional to the square of the velocity), momentum (proportional to the velocity) and species (particles of material carried by the fluid).

This invention involves the use of turbulence to manipulate the position, velocity and trajectories of very small pollutant particles carried by a flowing fluid, which is typically an exhaust gas stream from an industrial process, to increase the probability of their colliding with each other to agglomerate into larger, more easily removable particles, and/or to increase the probability of their colliding and interacting with a larger species of particles introduced into the fluid for the purpose of removing the pollutant particles.

In a preferred embodiment on the invention, this process involves two fundamental steps, namely:

1. Generation of turbulent flows of the appropriate scale (for the velocity and species of interest) to cause transportation (within the turbulence) of the small size fraction of the species carried by an industrial exhaust gas stream whilst having a diminishing ability to transport the larger size species.

2. Growth of the small scale turbulence into large scale turbulence that retains the ability to selectively transport species on the basis of their size, and encompasses the entire treatment passage so that all of the flowing fluid must pass through it.

The first criterion can be quantified by a Stokes number (St) range from $St << 1$ to $St >> 1$, for the complete size range of the species of interest in the flow environment of interest.

The Stokes number (St) is a theoretical measure of the ability of a particle to follow a turbulence streamline. The Stokes number is defined as the ratio of the particle response time to a fluid flow time and is characterised by:

$$St = \tau_p / \tau_f = \rho_p U d_p^2 / 18 \mu L,$$

where τ_p is the particle response time, τ_f is the characteristic flow time

and ρ_p is the particle density. Typically for St << 1 a particle is able to respond fully to the turbulent eddy of scale L, and follows it exactly. At the other extreme, where St >> 1, a particle does not respond to turbulent motions of that scale at all and the turbulent motions do not influence its trajectory. In the intermediate range, for St ≈ 1, particles respond partially to the fluid motions, but there is a significant departure of the particle trajectory from the fluid motions.

When a Stokes analysis is performed for a common pollution species in the flue of, for example, an industrial coal fired boiler, it is found that at the scale of a typical duct (say $4m^2$) and velocity of the gas (8–16 m/sec), all species of all size ranges will respond fully to the turbulence eddies, i.e. St << 1. Whilst for the turbulence scale corresponding to duct height/width mixers, turning vanes, stiffeners etc (say 400mm), the majority of particles below 100μm will respond fully to the turbulence eddies, i.e. St << 1. It is not until the turbulence scale is reduced to ≈10mm that the pollution species exhibit a range of responses from St << 1 to St >> 1 for sizes ranging from 0.1μm up to 100μm. At this scale, not only will the small size species be concentrated within the turbulence eddy (and more particularly at the axis of its rotation) but the larger size species not being influenced by the turbulence will travel through it on many trajectories and at varying velocities.

For mixing to be complete, it is necessary for the turbulence field being employed to encompass the entire duct. Hence this method involves the generation of a multitude of small scale turbulence eddies that combine to form a long range turbulence structure. It is important that this long range turbulence structure retains the ability to selectively transport the various size ranges of the species of interest at various velocities and on many trajectories. In this manner, the probability of species collision is increased and ultimately the collection rate of the pollutants of interest improved.

A physical embodiment of the present invention is described in Australian patent application no. 2003902014, a copy of which is annexed hereto and marked Annexure "A". The embodiment described in Annexure "A" is a passive (i.e. non-energized) agglomerator 10. The agglomerator 10 has a central duct section 12 having a plurality of longitudinal plates 13 which divide a gas stream into sub-

streams.

Emitter arrays 14 are located within each sub-stream, between adjacent plates 13. Each emitter array consists of a planar rectangular frame orientated in the direction of the gas flow. Each frame 18 has a plurality of spaced vertical emitter vanes 20. Each vane is typically a metal strip of "Z" section, angled to the direction of the gas flow.

The angled surfaces, sharp edges and discontinuous or zigzag formations of the emitter vanes 20 act as vortex generators, creating a multitude of vortices along each sub-stream. Moreover, the multitude of small vortices are propagated along the duct to form a relatively long range turbulence extending across the whole duct.

These vortices are of a very small size, and entrain fine pollutant particles in the gas stream. The fine particles are therefore subjected to turbulent flow, increasing the likelihood of collision between the particles and promoting a greater degree of agglomeration of the particles. The illustrated apparatus can also be used to promote mixing between the fine pollutant particles and a larger species of particles introduced into the gas stream to remove the pollutants. The small pollutant particles are entrained in the vortices, whereas the larger particles are not (or are entrained to a much smaller degree). The resultant differential movements and trajectories of the small pollutant particles and the larger removal particles results in greater mixing and collision between the two types of particles. Consequently, there is greater interaction between the particles (e.g impact adhesion, absorption,. adsorption or chemical reaction), improving the efficiency of pollutant removal by the removal species.

The foregoing describes only one embodiment of the invention, and modifications which are obvious to those skilled in the art may be made thereto without departing from the scope of the invention. For example, although the invention has been described with particular reference to the mixing of particles in a gas stream, it also has application to mixing in other fluid flows, e.g. liquids.

Conceptually, the invention involves matching the scale of the mixing to the scale of the species, and is not limited to any particular apparatus and process. Where the species are small (relative to their environment) and distributed sparsely, the turbulence regime used to mix them is reduced in scale to match that of the species in

order for them to be forced to interact energetically with each other. For example, to increase the mixing efficiency of widely separated flow species of the order of 0.1 – 100μm diameter, turbulence eddies need to be of the order of tens of mm and not the hundreds of mm that are presently employed in known vortex mixers. Further, optimum collision rates will occur for a system which maintains $St \ll 1$ to $St \gg 1$ for sizes ranging from 0.1μm up to 100μm. The turbulence itself may be generated in any suitable manner, and is not limited to vortices.

This mixing at particle scale improves inter and intra species mixing of any species in any flow medium and includes inter phase mixing. The mixing of the species of interest can be gas/solid, solid/solid, gas/gas, liquid/solid, etc.

Increased contact between the species carried by a fluid gives rise to higher absorption, adsorption, chemical interaction and adhesion rates of and between those species. This, in turn, gives rise to increased removal of pollutants from exhaust gases. Additionally the increased mixing efficiency may be used to reduce the length of the treatment zone whilst maintaining a current reaction/interaction level if, for example, space is important.

DATED this 9th day of February 2004
Indigo Technologies Group Pty Ltd
By Their Patent Attorneys
CULLEN & CO.

ANNEXURE "A"

PARTICLE AGGLOMERATION

This invention relates generally to air pollution control and, in particular, to apparatus and method for fine particle agglomeration in air streams to thereby facilitate subsequent filtration or other removal of the particles from the air streams.

The invention is particularly, but not solely, suitable for use with electrostatic precipitators.

BACKGROUND ART

Many industrial processes result in the emission of small hazardous particles into the atmosphere. These particles often include very fine sub-micron particles of toxic compounds. As these fine particles are able to enter the human respiratory system, they pose a significant danger to public health. The identified combination of toxicity and ease of respiration has prompted governments around the world to enact legislation for more stringent control of emission of particles less than ten microns in diameter (PM10), and particularly particles less than 2.5 microns (PM2.5).

Smaller particles in atmospheric emissions are also predominantly responsible for the adverse visual effects of air pollution. For example, in coal burning installations, stack opacity is largely determined by the fine particulate fraction of the fly ash because the light extinction coefficient peaks near the wavelength of light which is between 0.1 and 1 microns.

The importance of fine particulate control can be appreciated by consideration of the number of pollutant particles in an emission rather than the pollutant mass. In fly ash from a typical coal combustion process, pollutant particles less than 2 microns in size may amount to only 7% of the total pollutant mass, yet account for 97% of the total number of particles. A process which

removes all the particles greater than 2 microns may seem efficient on the basis that it removes 93% of the pollutant mass, yet 97% of the particles remain, including the more respirable toxic particles.

Various methods have been used to remove dust and other pollutant particles from air streams. Although these methods are generally suitable for removing larger particles from air streams, they are usually much less effective in filtering out smaller particles, particularly PM2.5 particles.

It is known to use particle agglomeration techniques to combine smaller particles into larger particles, which can then be removed more easily or effectively. Known agglomeration techniques include: (i) injection of chemicals into air streams to increase agglomeration of fine particles, (ii) use of laminar flow precipitators to promote surface agglomeration of fine particles, (iii) acoustic agitation of dust particles suspended in a gas to increase impingement and hence agglomeration rates, (iv) AC or DC electric field agitation of charged dust particles suspended in a gas to increase mixing and hence agglomeration, and (v) bipolar charging of particles in a gas stream for electrostatic attraction.

These techniques are usually costly to implement in large scale installations, and the chemical injection method raises other health concerns. Further, the known techniques are not particularly efficient in relation to fine dust particles.

Our international patent application WO 01/34854 describes a method and apparatus for particle agglomeration in which particles in a gas stream are charged to opposite polarities by an ion generator, and the flow of the gas stream is then altered physically downstream of the ion generator to cause mixing of oppositely charged particles, and thereby promote agglomeration of the particles. In one embodiment, the

ion generator is a bipolar DC ionizer which charges particles in adjacent portions across the gas stream to opposite polarities. The DC ionizer comprises a plurality of spaced electrode arrays arranged transversely across the gas stream, each electrode array being connected to a DC voltage and adjacent electrode arrays being of opposite polarity. Earthed planar members are located between the electrode arrays and oriented parallel thereto, and provide earthed surfaces. The disclosure of that patent application is incorporated herein by reference.

In test results, apparatus constructed in accordance with the teachings of international patent application WO 01/34854 has proved to be effective in agglomerating fine particles into larger particles which can be removed more easily from the airstream.

Surprisingly, it has now been found that fine particle agglomeration can be achieved using apparatus generally similar to that described in application WO 01/34854, but without an energized ionizer, i.e. using a mostly passive structure to achieve particle agglomeration.

SUMMARY OF THE INVENTION

In one broad form, this invention provides apparatus for agglomerating particles in a gas stream, comprising

a duct section through which the gas stream flows in use, the duct section having a plurality of spaced parallel non-energized plate members orientated generally in the direction of flow of the gas stream so that the gas stream flows between the plates, and

a mixing formation located downstream of the plate members for physically altering the flow of the gas stream and causing mixing of particles to thereby promote agglomeration of the particles.

In another form, the invention provides a method of promoting agglomeration of particles in a gas stream, comprising the steps of

passing the gas stream through a duct section having a plurality of spaced parallel non-energized plate members orientated generally in the direction of flow of the gas stream so that the gas flows between the plates, then

passing the gas stream through a mixing formation located downstream of the plate members to physically alter the flow of the gas stream and cause mixing of particles, to thereby promote agglomeration of the particles.

Typically, the plate members are earthed plates suspended from the roof of the duct section.

Preferably, emitter arrays are located between, and parallel to, adjacent pairs of plate members. Each emitter array may comprise a planar rectangular frame in which spaced parallel emitter vanes are mounted. Each emitter vane is suitably a metal strip of angled section. Preferably, the emitter vanes are orientated obliquely to the gas flow and promote turbulence of the gas stream between the planar members.

The mixing formation preferably comprises spaced parallel rows of spaced posts, each row extending transversely across the flow of the gas stream, with the posts in each row being staggered with respect to the posts in the preceding row. Typically, two rows of mixing posts are provided, and the posts in the second row are of larger diameter than those in the first row.

In order that the invention may be more fully understood and put into practice, a preferred embodiment thereof will now be described by way of example only, with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic plan view of an agglomerator according to one embodiment of the invention.

Fig. 2 is a schematic sectional side elevation of the agglomerator of Fig. 1.

Fig. 3 is a schematic sectional end elevation of the agglomerator of Fig. 1.

Fig. 4 is an enlarged schematic sectional plan view of a portion of an emitter of the agglomerator of Fig. 1.

DESCRIPTION OF PREFERRED EMBODIMENT

As shown in Figs. 1 - 3, an agglomerator 10 has three sections. A first section forms an inlet duct 11 which receives a flow of gas containing particles to be agglomerated. The inlet duct 11 directs the gas stream to a central duct section 12.

The central section 12 contains a series of parallel earthed plates 13 which are orientated longitudinally (i.e. in the general direction of the gas flow) and spaced across the width of the central section 12. Each earthed plate 13 is suspended from the roof 16 of the central duct section 12, above the duct floor 17.

Located centrally between the earthed plates 13, and parallel thereto, are emitter arrays 14. As shown more clearly in Fig. 4, each emitter array 14 consists of a planar rectangular frame 18 which is suspended from the duct roof 16 by respective insulators 15. Each emitter frame 18 is located centrally between a pair of earthed plates 13 and parallel thereto.

Each emitter frame 18 has a plurality of spaced vertical emitter vanes 20 mounted generally within the plane of the frame 18, and retained in position by emitter mounts 19 in which the emitter vanes are located. Each emitter vane 20 is typically a metal strip of "Z" section,

angled to the direction of gas flow between the earthed plates 13.

The agglomerator 10 also has a mixing section 21 located downstream from the central section 12. The mixing section 21 is a duct which contains a plurality of spaced posts, typically tubular posts. A first row of spaced posts 22 are arranged in a transverse plane, i.e. the posts 22 are spaced across the width of the mixing duct section 21.

A second row of spaced posts 23 are also arranged in a transverse plane across the width of the mixing duct section 21, as can be seen in Figs. 1 and 2. The second posts 23 are staggered relative to the first row of posts 22, i.e. each second post 23 is located between a pair of first posts 22, but downstream thereof. The second posts 23 are preferably of larger diameter than the first posts 22. Typically, the first posts 22 are about 150mm in diameter, and the second posts 23 are about 200mm in diameter.

In use, exhaust gas from an industrial process is channeled to the inlet duct section 11 of the agglomerator 10. This gas stream will contain suspended particles. Typically, some of the particles have been charged by a triboelectric effect, e.g. as they pass between the rear of a boiler and a air heater in a coal burning power station, or generally through surface friction as the particles flow through ducts and passages.

The gas stream from the inlet section 11 flows between the parallel earthed plates 13, and the charged particles in the gas flow between the earthed plates 13 create an electric field due to the space charge generated by the suspended charged particles. The larger particles will be attracted to the earthed plates 13, and this may have a beneficial effect on the overall performance of the agglomerator.

The emitter arrays 14 located between the earthed plates 13 may be floating electrically and hence

will charge up due to the charged particles impacting thereon. Alternatively, the emitter arrays may be earthed.

The emitter vanes 20 are angled to the direction of gas flow, and cause turbulence and mixing of the gas and particles within the passages between the earthed plates 13. Such turbulence and mixing may enhance the agglomeration of the particles.

After the gas flow passes through the central section 12 it enters the mixing section 21 and impinges upon the staggered mixing posts 22, 23. It is believed that the mixing posts 22, 23 enhance agglomeration by altering the gas flow to force the particles together in an energetic manner, and do so not only for particles within an individual passage between a pair of earthed plates 13, but also particles in adjacent passages.

The abovedescribed apparatus is a "passive" agglomerator, i.e. it need not be energized or powered in order to achieve substantial agglomeration of particles in the gas flow. This enables the agglomerator to be constructed and operated at significantly less cost than known agglomerators.

The agglomerator of this invention provides improved collection efficiency of the fine dust fraction from large process plant exhaust streams, with resulting environmental and health benefits. The agglomeration of fine particles facilitates the removal of particles which are the most visible, contain the highest concentration of heavy metals and other toxins, are the most mobile (atmospherically) and are the most respirable for humans.

The foregoing describes only one embodiment of the invention, and modifications may be made thereto without departing from the scope of the invention. For example, the shape and placement of the mixer posts 22, 23 can be varied.

Furthermore, the abovedescribed apparatus can be used for other purposes, e.g. for mixing dust particles

and chemical additives (such as SO_3 and NH_3 condensate) together prior to a precipitator to create particle agglomerates in the gas stream.

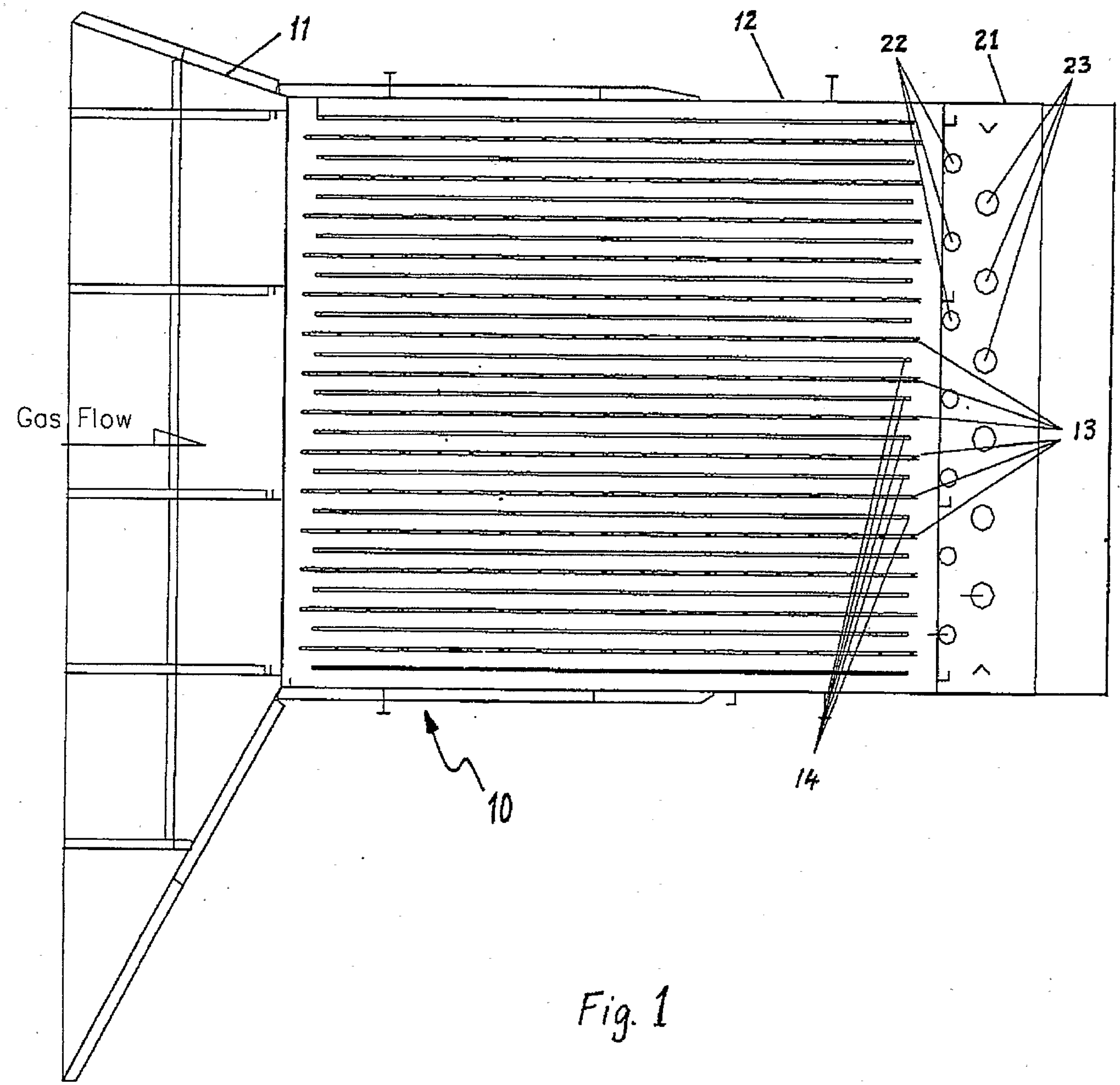

Fig. 1

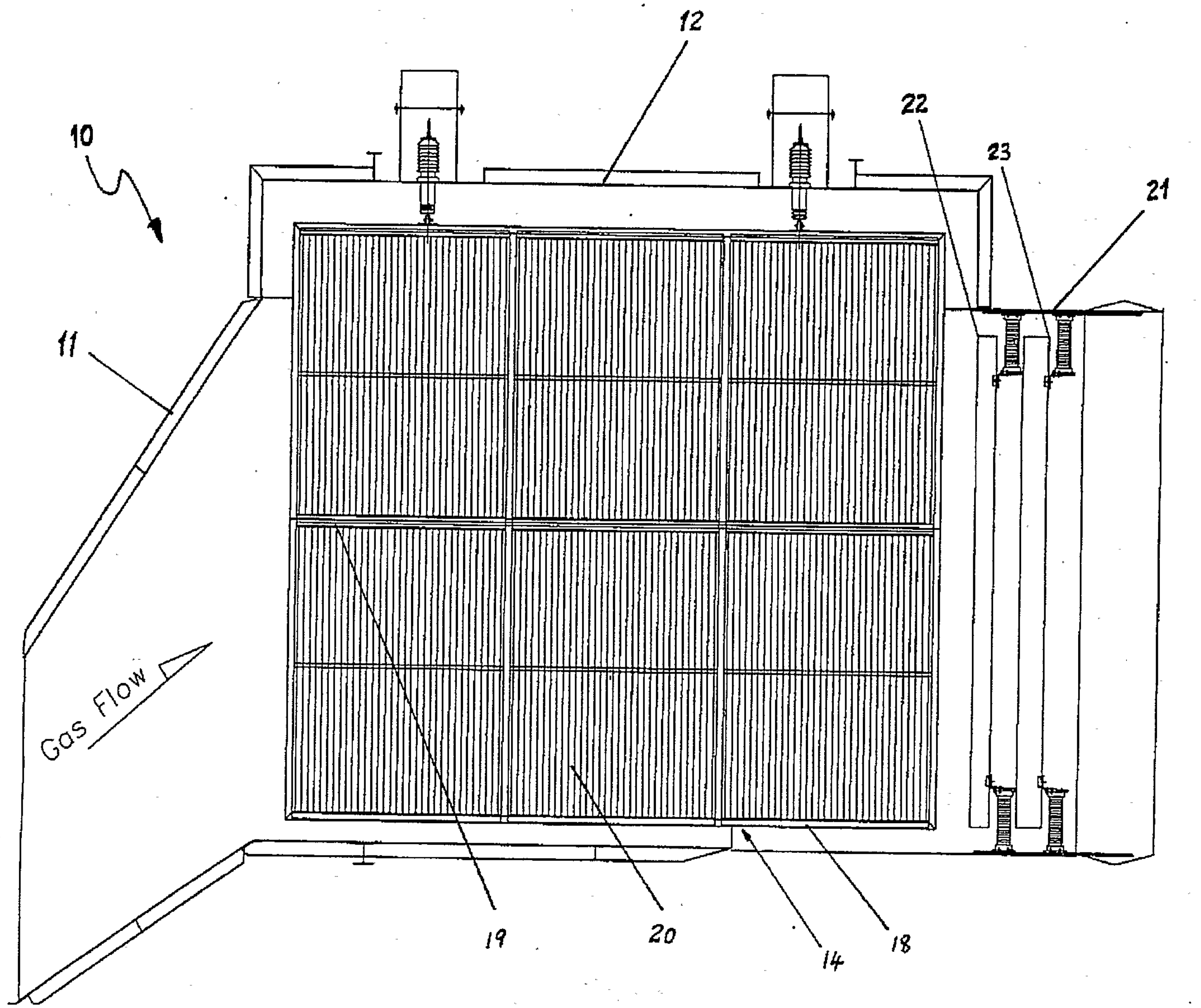

Fig. 2

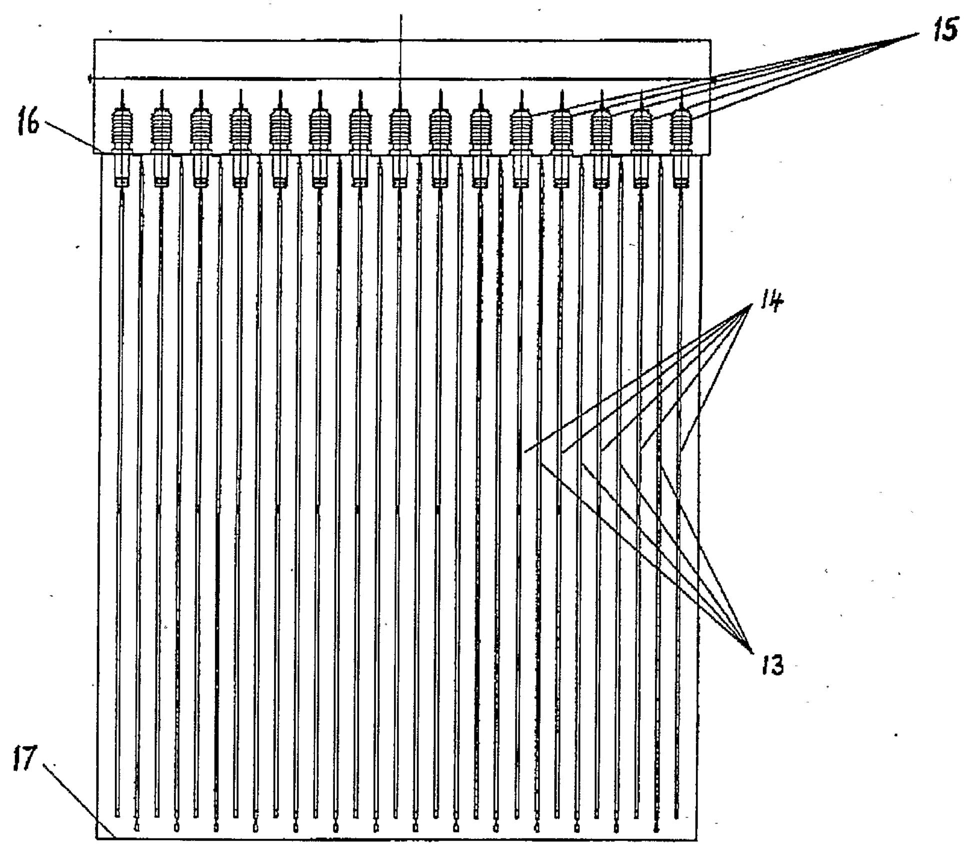

Fig. 3

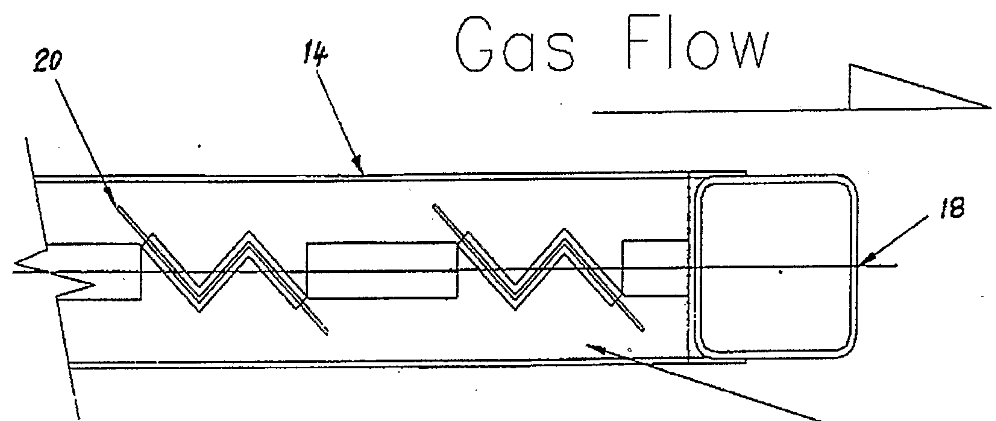

Fig. 4